THE EFFECTS OF APPROVED CORROSION INHIBITORS ON THE PERFORMANCE OF MILITARY STANDARD FILTER/SEPARATORS

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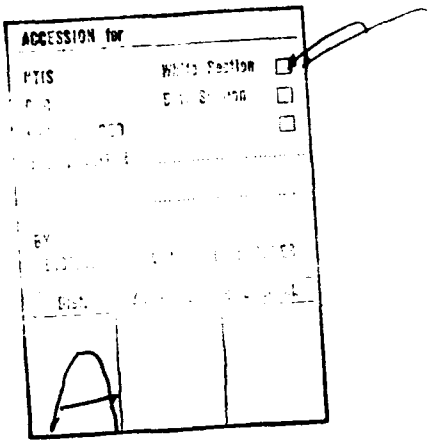
November 1974



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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: 2117	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: AD/A-006492	
4. TITLE (and Subtitle): THE EFFECTS OF APPROVED CORROSION INHIBITORS ON THE PERFORMANCE OF MILITARY STANDARD FILTER/SEPARATORS	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Shirley B. Boulware	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Fuels Handling Equipment Division, Petroleum and Materials Department, U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1G762708D50606
11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia	12. REPORT DATE: November 1974
	13. NUMBER OF PAGES: 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Filter/Coalescer Element
Filter/Separator
Corrosion Inhibitor
Water Coalescence
Solids Removal
Surfactants

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This final report covers an investigation of 12 corrosion inhibitors specified in Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble," in combination with the anti-icing additive (AIA) specified in Specification MIL-I-27686, "Inhibitor, Fuel System, Icing." These inhibitors are used in JP-5 fuel in accordance with Specification MIL-F-8901, "Filter/Separators, Liquid Fuel; and Filter/Coalescer Elements, Fluid Pressure; Inspection Requirements and Test Procedures For." Performance data is gathered in order to

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Block 20 continued:

determine if a military standard filter/coalescer element is capable of decontaminating inhibited JP-5 fuel as it is continuously injected with water and with water/solids combinations.

The report concludes that 4 of the 12 corrosion inhibitors on the present Qualified Products List in combination with the AIA "poisoned" the ability of the filter/coalescer element to remove water and solid contaminants from fuels and should be recalled for additional tests to verify their inclusion on the QPL.

PREFACE

Authority for conducting research described in this report is contained in The Catalog of Approved Requirement Documents (CARDS) under Project No. 1G762708D50606.

This research is being conducted in the Fuels Surveillance and Technology Branch, Fuels Handling Equipment Division, Petroleum and Materials Department, U. S. Army Mobility Equipment Research and Development Center (USAMERDC), Fort Belvoir, Virginia.

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I. INTRODUCTION

1. Subject. This report covers an investigation of 12 corrosion inhibitors specified in Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble," in combination with the anti-icing additive (AIA) specified in Specification MIL-I-27686, "Inhibitor, Fuel System, Icing." These inhibitors are used in JP-5 fuel in accordance with Specification MIL-F-8901, "Filter/Separators, Liquid Fuel: and Filter/Coalescer Elements, Fluid Pressure: Inspection Requirements and Test Procedures For." Performance data are gathered in order to determine if a military standard filter/coalescer element is capable of decontaminating inhibited JP-5 fuel as it is continuously injected with water and with water/solids combinations.

2. Purpose of Tests. Chemical additives are frequently incorporated into military fuels to enhance their physical properties and performance criteria. Field experience has indicated that surface-active agents (surfactants) have been the cause of filter/coalescer element failures. The surfactants were thought to be the cause of filter/separator failure by "poisoning" the ability of the filter/separator to remove water and solid contaminants from fuels. (The filter/coalescer element is an integral part of the filter/separator.) The purpose of these tests was to determine the effects of 12 corrosion inhibitors specified in MIL-I-25017 in combination with the AIA specified in MIL-I-27686 on the performance of military standard filter/separators.

Of the 12 corrosion inhibitors, Hitec E-515 (formerly Santolene-C), AFA-1, Lubrizol 541, Tolad 244, and Tolad 245 were on the Qualified Products List (QPL) which preceded the list now in effect. These corrosion inhibitors were investigated in an earlier publication by the author. In the previous report the use of an anti-icing additive in combination with the corrosion inhibitor was not incorporated in the inhibited test because the filter/coalescer element lay-up configuration conformed to the performance requirements of an earlier version of MIL-F-8901 which stipulated the use of only one additive – a corrosion inhibitor – in the inhibited fuel test.

The corrosion inhibitors used in the present evaluation were as follows: Hitec E-515* and Hitec E-534, manufactured by Edwin Cooper, Inc.; AFA-1 and DCI-4A, by E. I. Du Pont De Nemours; Nalco 5400-A and Nalco 5402, by Nalco Chemical Co.; Tolad 244 and Tolad 245, by Tretolite Division; Lubrizol-541, by Lubrizol

*Formerly known as Santolene C

Corp.; PRI-19, by Apollo Chemical Co.; Unicor-j, by UOP Process Division: and Conoco T-60, by McNutt Industries.

3. **Background.** Qualified Products List QPL-25017 contains the corrosion inhibitors that are approved for use in military fuels (see Table 1).

Table 1. Qualified Products List of Corrosion Inhibitors

Corrosion Inhibitor	Manufacturer	Approved for Fuels Meeting Specifications Listed Below				
		VV-G-001690 Automotive Gas Low Lead & Unlead	VV-G-76 Automotive Gas	MIL-C-3056 Automotive Combat Gasoline	MIL-G-5572 Aviation Gas	MIL-T-5624 JP-4 and JP-5 Turbine Fuels
1. AFA-1	E.I. DuPont De Nemours Co.	+	+	+	+	+
2. Lubrizol 541	Lubrizol Corp.	+	+	+	+	+
3. Tolad 244	Tetrolite Div.	+	+	+	+	+
4. Tolad 245	Tetrolite Div.	+	+	+	–	+
5. PRI-19	Apollo Chem. Co.	+	+	+	–	+
6. Hitec E-515	Edwin Cooper, Inc.	+	+	+	–	+
7. Hitec E-534	Edwin Cooper, Inc.	+	+	+	–	+
8. DCI-4A	E.I. DuPont De Nemours Co.	+	+	+	–	+
9. Unicor-J	U.O.P. Process Div.	+	+	+	–	+
10. Nalco 5400-A	Nalco Chem. Co.	+	+	+	–	+
11. Nalco 5402	Nalco Chem. Co.	–	–	–	–	+
12. Conoco T-60	McNutt Ind.	–	–	–	–	+

NOTE: + approved.
– *not approved.*

Hitec E-515 is the only corrosion inhibitor specified in the inhibited test of MIL-F-8901. It has been extensively used in performance tests at these laboratories and has never presented a major problem with the military standard filter/coalescer element. Water and solids removal data have been collected on AFA-1, Lubrizol-541, Tolad 244, and Tolad 245 during previous tests. The remaining corrosion inhibitors have never been tested by these laboratories. With the introduction of an anti-icing additive in combination with a corrosion inhibitor, it became extremely important to test not only the new corrosion/AIA inhibitor combinations but also to test those inhibitors already tested by these Laboratories as they react with anti-icing additives.

II. INVESTIGATION

4. Description of Test Facility. A closed test loop, portions of which were glass, was used to conduct the inhibited fuel test. The loop consisted of two 3000-gallon storage tanks, a 20 gallon per minute (gpm) centrifugal pump, water-injection equipment, sample withdrawal apparatus, a clean-up filter/separator, a fuller's earth clay filter, and suitable instrumentation (see Figure).

5. Test Filter/coalescer Elements. Of the five different manufacturers on the present filter/coalescer element QPL, only one manufacturer was selected for this investigation so as to minimize the number of variables. The filter/coalescer elements, in accordance with MIL-F-8901, were either elements taken from a lot at USAMERDC for quality-control testing or ordered directly from depot stock. The elements on hand for quality-control tests were not used until it was verified that the lot from which they came was acceptable.

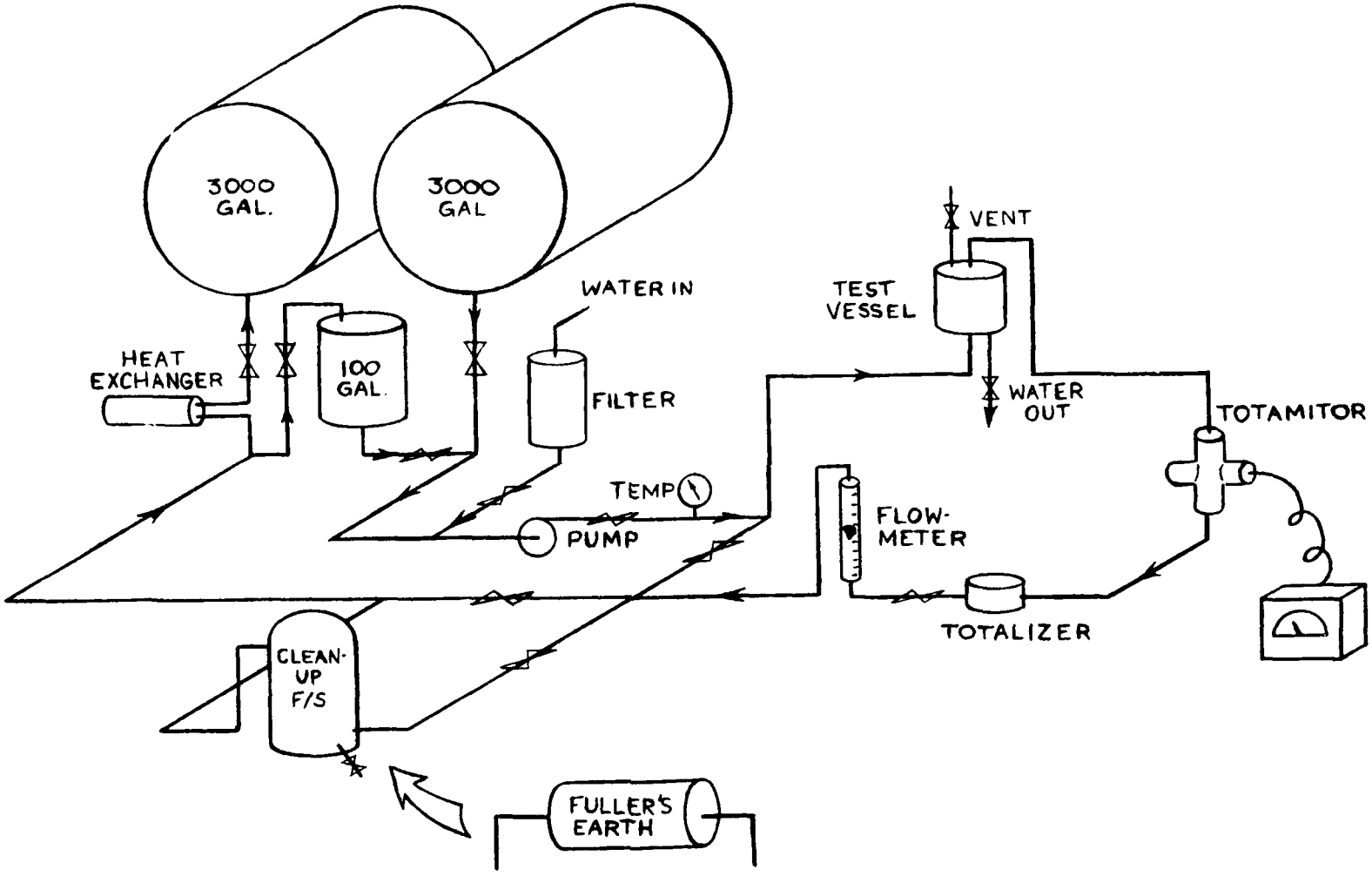
6. Performance Requirements. The performance requirements according to MIL-F-8901 are as follows:

a. The effluent fuel when measured by in-line instrumentation shall not exceed 5 parts per million (ppm) by volume of undissolved (free) water. One percent water shall be injected into the influent fuel.

b. While 1% water and 0.143 gram per gallon of solids are injected, the filter/coalescer element shall remove solid contaminants to the extent that not more than 1.0 milligram per liter of solid contaminant shall be in the average 1-liter effluent fuel sample. In this investigation, however, liter samples of fuel were not taken because it was to be accepted as sufficient proof of passing or failing that the Turbidimeter (in-line instrumentation) would indicate total contamination whether it be in the form of solids or water. To this end, a difference of 5 ppm or more between the blank Turbidimeter reading and readings while contaminants were being injected was to be the criterion.

c. The pressure differential across the filter/coalescer element at rated flow shall not exceed 20 pounds per square inch (psi) before 30 minutes nor 40 psi before 70 minutes at a solids injection rate of 0.143 gram per gallon while 1% by volume of water is being injected.

7. Test Fuel and Contaminants. The test fuel used in this investigation was JP-5 conforming to MIL-T-5624. The fuel was initially treated (or cleaned) with fuller's earth to insure a high Water Separometer Index (Modified) (WSIM). The WSIM was 96 prior to the addition of inhibitors. Data are recorded stating WSIM's after the addition



GLASS TEST LOOP – BUILDING 341

of specific inhibitor concentrations.

The water used as a test contaminant was filtered prior to being injected into the fuel. Its residual-solids level was less than 1 milligram per Liter and the pH factor varied from 6.5 to 7.0. The water was supplied by the Fort Belvoir water utility system.

The solid contaminant used was AC Spark Plug Co. test dust, coarse grade, package no. 1543637, obtained from the AC Spark Plug Co., Flint, Michigan.

8. **Sample Analysis Procedures.** Samples were analyzed for free water and solids content and water-separation properties.

The Keene Turbidimeter (Model 861-B) was employed as an in-line monitoring device. It operates on a light-scattering principle by detecting minute water droplets and solid particles with diffused or reflected light beams. The magnitude of light scattering is indicated on a dial (galvanometer) scaled to read in ppm of free water and solids.

Water-separation properties of the fuel were determined with a Water Separometer. This instrument measures the WSIM which is an indication of the ability of a fuel or a fuel/additive combination to release entrained or emulsified water when the fuel is passed through a coalescer-type water separator.

9. **Test Procedures and Results.** Prior to the initiation of tests, 3000 gallons of JP-5 fuel were treated by passing the fuel through fuller's earth filters to obtain a minimum WSIM number of not less than 85. At the start of each test, appropriate quantities of corrosion and anti-icing additive inhibitors were added to one of the 3000-gallon storage tanks containing the test fuel (see Figure) and blended for 20 minutes by circulation while bypassing the test vessel and clean-up filter/separator.

A new filter/coalescer element, installed in the vertical test vessel, was used with the test run for each corrosion/AIA inhibitor combination.

Upon completion of blending, the fuel was pumped through the test system, including the clean-up filter/separator, at 20 gpm to obtain blank Turbidimeter and pressure readings.

One-percent water was injected for 60 minutes at the pump inlet, followed by an additional 70 minutes in which 1% water and 0.143 gram per gallon of AC dust were injected. Turbidimeter and pressure readings were recorded every 10 minutes of the 130-minute test. These inhibited tests were run in accordance with MIL-F-8901.

In the event a filter/coalescer element failed during a test, that particular

element was taken out of the test vessel and immersed in inhibited JP-5 fuel for further tests. Another new, clean, and dry filter/coalescer element was then put into the test vessel and subjected to the same 1% water and solids removal test described above. If this filter/coalescer also failed, it remained in the test vessel. The procedures of cleaning up (or removing the inhibitors from) the JP-5 fuel with water and fuller's earth would then be carried out while the test vessel was bypassed. After the fuel was cleaned up, the filter/coalescer element in the test vessel was subjected to a 1% water removal test. Then, the first filter/coalescer element, which had been immersed in inhibited JP-5 fuel up to this point, was placed in the test vessel upon removal of the other element and was also subjected to a 1% water removal test. These tests were performed in order to verify the cause of the failure. If the filter/coalescer element failed to decontaminate inhibited JP-5 fuel and also failed to decontaminate uninhibited JP-5 fuel, the cause of failure of the original test would be attributed to a defective filter/coalescer element. If the filter/coalescer failed to decontaminate inhibited JP-5 fuel but successfully decontaminated uninhibited JP-5 fuel, the cause of failure of the original test would be attributed to the corrosion/AIA inhibitor combination.

At the completion of each corrosion/AIA test, the JP-5 fuel was subjected to fuller's earth treatment for three complete passes through the clay cartridges in order to remove the corrosion inhibitor from the fuel. Two-percent water was injected at the inlet side of the pump during the first pass to remove the AIA in the fuel. The JP-5 fuel was treated with fuller's earth until the WSIM was not less than a minimum of 85.

Results of the tests are recorded in Tables A2 through A14 in the Appendix.

III. DISCUSSION

10. Evaluation of Results. The Air Force Aero Propulsion Laboratory (SFF) is responsible for the Qualified Products List dated 3 November 1973. This QPL is coordinated with the Army, Navy, and other user activities.

The corrosion inhibitors are qualified in accordance with Specification MIL-I-25017 "Inhibitor, Corrosion, Fuel Soluble." The specification does not specifically call for direct testing of filter/coalescer elements using specified combinations of corrosion/AIA inhibitors in JP-5 fuel. However, in this investigation, 4 of the 12 corrosion inhibitors were found to be unsatisfactory when used in combination with AIA as required by the inhibited fuel test of MIL-F-8901. These findings warrant action to re-evaluate the four unsatisfactory corrosion inhibitors on the Qualified Products List.

IV. CONCLUSIONS

11. Conclusions. This laboratory concludes that the following corrosion inhibitors should be re-evaluated by the responsible agency to reconfirm their inclusion on the QPL:

a. Lubrizol 541, Lubrizol Corp.
b. Tolad 245, Tetrolite Div.
c. PRI-19, Apollo Chem. Co.
d. Nalco 5402, Nalco Chem. Co.

Lubrizol 541 and Tolad 245 were on previous QPL's and successfully passed inhibited tests in accordance with the earlier Specification MIL-F-8901. But, no corrosion/AIA inhibitor combination was required in that specification. The current Specification MIL-F-8901, however, requires corrosion/AIA inhibitor combinations in its inhibited fuel test. This may be the reason why the four corrosion inhibitors outlined in a through d, above, in combination with AIA failed to pass the inhibited test.

APPENDIX

TEST DATA

Table A2. Santolene-C (Hitec E-515) and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 16 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 47 Water Injection: 1%
AC Dust Injection: 0.143 g/gal
F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	69	5.5	1.9
10	20	69	7.5	2.1
20	20	68	8.9	2.3
30	20	68	10.0	2.5
40	20	69	10.0	2.5
50	20	68	10.0	2.7
60	20	68	11.0	2.9
61 – AC Dust on	–	–	–	–
70	19	68	–	3.0
80	18.5	68	12.5	3.3
90	18	68	14.0	3.2
100	18.5	68	15.0	3.3
110	17	68	15.0	3.4
120	16.5	68	16.0	3.4
130	16	68	–	3.4 Pass

Table A3. AFA-1 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 12 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 41

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	80	6.0	1.6
10	20	82	8.0	1.7
20	20	81	8.0	1.9
30	20	82	8.0	1.9
40	20	82	8.0	1.9
50	20	82	9.0	1.9
60	20	82	9.0	2.0
61 – AC Dust on	—	–	–	–
70	20	82	10.0	2.1
80	–	81	9.5	2.1
90	–	81	10.0	2.1
100	–	81	10.5	2.1
110	–	81	10.5	2.1
120	–	81	9.5	2.1
130	–	–	–	2.1 Pass

Table A4. Lubrizol 541 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 6 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 41

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner. Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	87	6.0	1.8
10	20	88	8.0	2.8
20	20	88	8.0	4.3
30	20	88	8.0	4.9
40	20	88	9.0	5.4
50	20	87	9.5	6.3
60	20	87	9.5	7.0
				Failure #1
0	20	90	5.5	1.5
10	20	90	8.0	2.2
20	20	90	9.0	3.0
30	20	90	9.5	3.2
40	20	90	10.0	3.7
50	20	90	11.0	4.2
60	20	90	11.5	5.2
61 – AC Dust on	–	–	–	–
70	20	90	12.0	5.6
80	19	90	13.0	5.8
90	18.5	90	13.0	6.4
100	17.5	90	15.0	6.5
110	17	90	–	7.4
				Failure #2
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #2 using uninhibited JP-5. Inject 1% water.				
0	17.5	84	16.5	2.4
10	17	86	18.5	1.9
20	17	88	18.5	1.9
30	16.5	88	18.0	1.9
40	16.5	88	18.0	1.9
50	16	88	18.0	1.9
60	16	89	18.0	1.9
				Pass

Table A5. Tolad 244 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 6 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 60

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (^{O}F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	86	6.0	2.1
10	20	86	9.0	2.9
20	20	86	9.5	3.4
30	20	86	10.5	3.7
40	20	86	11.5	4.2
50	20	86	12.0	4.4
60	20	86	12.0	4.6
61 – AC Dust on	–	–	–	–
70	20	86	13.0	5.9
80	19	86	–	5.8
90	18	86	14.5	5.3
100	17.5	86	14.5	5.2
110	17	86	16.0	5.0
120	16	87	17.0	4.8
130	16	87	17.5	4.5 Pass

Table A6. Tolad 245 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 12 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 71

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	88	6.0	2.0
10	20	88	9.5	3.0
20	20	89	11.0	5.0
30	20	–	12.0	7.4
				Failure #1
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #1 using uninhibited JP-5. Inject 1% water.				
0	19.5	86	10.5	2.8
10	19.5	86	11.0	2.1
20	19	86	13.0	2.2
30	19	86	13.5	2.2
40	19	86	13.5	2.2
50	19	86	–	2.2
60	19	86	–	2.2
				Pass #1
0	20	88	6.0	2.1
10	20	89	9.0	2.1
20	20	90	9.5	2.4
30	20	90	9.0	2.7
40	20	90	13.0	3.6
50	19	90	14.0	4.5
60	19.5	90	–	5.6
61 – AC Dust on	–	–	–	–
70	18.5	89	18.0	8.6
80	17	89	19.0	8.6
90	16	–	–	8.0
				Failure #2
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #2 using uninhibited JP-5. Inject 1% water.				

Table A6 (cont'd)

Time (min)	Fuel Flow (gpm)	Fuel Temperature (^{O}F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	17	86	17.0	2.3
10	17	86	16.0	2.1
20	15.5	86	19.0	2.4
30	15.5	86	19.0	2.4
40	15.5	86	19.0	2.4
50	15.5	86	19.0	2.4
60	15.5	86	19.0	2.4
				Pass #2

Table A7. Apollo PRI-19 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 4 lb/1000 bbl
AIA concentration: 0.15%
WSIM: 46

Water Injection: 1%

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	74	8.5	2.3
10	20	74	9.0	2.7
20	20	74	10.0	3.6
30	20	74	10.5	4.4
40	20	74	11.5	5.4
50	20	74	11.5	6.2
60	20	74	12.0	7.6
				Failure #1
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #1 using uninhibited JP-5. Inject 1% water.				
0	20	74	9.0	2.1
10	20	73	10.5	2.3
20	19.5	73	12.5	2.3
30	19	74	12.5	2.3
40	19	74	12.5	2.3
50	19	74	12.5	2.2
60	19	–	–	2.2
				Pass #1
0	20	71	7.0	2.3
10	20	72	11.0	3.7
20	20	72	11.5	5.3
30	20	72	12.0	7.8
				Failure #2
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #2 using uninhibited JP-5. Inject 1% water.				
0	20	70	10.5	2.2
10	19.5	71	12.5	2.5
20	19.5	71	13.5	2.4
30	19	72	13.5	2.4
40	19	72	13.5	2.4
50	19	72	13.5	2.4
60	19	72	13.5	2.4
				Pass #2

Table A8. Santolene CM (Hitec E-532) and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 8 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 52

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (^{o}F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	71	8.0	2.3
10	20	70	10.0	2.5
20	20	70	11.5	2.5
30	20	70	12.0	2.6
40	20	70	12.0	2.7
50	20	70	12.0	2.9
60	19.5	70	13.0	3.1
61 – AC Dust on	–	–	–	–
70	19.5	70	12.0	2.7
80	19	70	12.5	2.7
90	18	70	14.0	2.7
100	18	70	14.0	2.7
110	18	70	14.0	2.8
120	17.5	70	14.0	2.8
130	17	70	15.0	2.8
				Pass

Table A9. DCI-4 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 8 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 50

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	90	8.0	2.5
10	20	90	11.0	2.5
20	20	90	11.0	2.5
30	20	90	10.5	2.5
40	20	90	11.0	2.6
50	20	90	11.5	2.6
60	20	90	12.0	2.7
61 – AC Dust on	–	–	–	–
70	20	90	12.0	2.7
80	20	90	12.0	2.7
90	19.5	90	11.5	2.8
100	19	90	12.0	2.8
110	19	90	12.0	2.9
120	19	90	12.0	2.9
130	18.5	90	12.0	2.9 Pass

Table A16. Conoco T-60 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 16 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 51

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	78	3.5	2.3
10	20	78	9.5	2.3
20	20	78	9.5	2.3
30	20	78	11.0	2.3
40	20	78	11.5	2.3
50	20	78	11.5	2.3
60	20	78	11.5	2.3
61 - AC Dust on		–	–	–
70	19	76	11.5	2.6
80	19	76	11.0	2.5
90	18	77	11.0	2.5
100	18	77	11.0	2.4
110	18	78	11.5	2.4
120	17.5	78	12.0	2.4
130	17	78	12.0	2.4 Pass

Table A11. Nalco 5400-A and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 8 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 45

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	80	11.0	3.0
10	20	80	12.0	3.0
20	20	80	12.5	3.1
30	20	80	11.5	3.2
40	20	80	11.5	3.3
50	20	80	12.5	3.4
60	19.5	80	12.5	3.4
61 – AC Dust on	–	–	–	–
70	19.5	80	12.0	3.3
80	19.0	82	12.0	3.1
90	18.5	82	13.0	3.2
100	18.5	82	13.5	3.0
110	17.5	82	14.0	2.9
120	17.5	82	14.0	2.9
130	17.5	82	15.0	2.9
				Pass

Table A12 Unicor-J and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 8 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 63

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	73	5.0	2.1
10	20	73	7.5	2.2
20	20	73	8.0	2.2
30	20	73	7.5	2.2
40	20	73	8.0	2.2
50	20	73	8.0	2.2
60	20	73	9.0	2.2
61 – AC Dust on	–	–	–	–
70	20	73	9.0	2.2
80	20	73	11.0	2.2
90	19.5	73	11.0	2.2
100	19	73	11.0	2.2
110	18	73	14.0	2.2
120	17	73	15.0	2.2
130	15.5	73	17.0	2.2 Pass

Table A13. Nalco 5402 and Anti-Icing Additive Data

Corrosion Inhibitor Concentration: 8 lb/1000 bbl
AIA Concentration: 0.15%
WSIM: 48

Water Injection: 1%
AC Dust Injection: 0.143 g/gal

F/C Element: Banner, Model No. C-2037-3

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
0	20	85	7.0	2.0
10	20	85	10.0	3.0
20	20	85	11.5	3.8
30	20	85	12.0	4.6
40	20	85	12.5	5.1
50	20	85	10.0	5.7
60	20	85	12.0	5.8
61 – AC Dust on	–	–	–	–
70	20	85	14.0	9.4 Failure #1
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #1 using uninhibited JP-5. Inject 1% water.				
0	19	88	10.0	2.1
10	19	86	13.0	2.4
20	19	86	13.0	2.3
30	19	87	13.0	2.3
40	19	88	13.0	2.3
50	19	88	13.0	2.3
60	19	89	13.0	2.3 Pass #1
0	20	87	9.0	1.9
10	20	86	12.0	2.8
20	19	86	13.5	3.4
30	18.5	87	14.0	3.5
40	18	87	14.0	3.7
50	18	87	14.0	3.7
60[a]	18	87	14.0	3.8
61 – AC Dust on	–	–	–	–

Table A13 (cont'd)

Time (min)	Fuel Flow (gpm)	Fuel Temperature (°F)	Differential Pressure (psi)	Turbidimeter (ppm)
70	18.5	85	13.5	6.9
80	18	85	15.0	6.2
90[b]	17.5	85	16.5	5.2
95	18.5	86	16.5	7.8
				Failure #2
Remove additives from JP-5 with fuller's earth and water. Retest above element that produced failure #2 using uninhibited JP-5. Inject 1% water.				
0	18	83	14.5	1.8
10	17	86	16.0	2.5
20	17	86	17.0	2.4
30	17	86	17.0	2.4
40	17	87	17.0	2.3
50	17	87	17.0	2.3
60	17	87	17.0	2.3
				Pass #2

(a) Test was stopped after 60 minutes to re-clean and re-inhibit fuel so as to have ample supply for remainder of test. *Total* = 2 days stoppage.

(b) Test was stopped. Moyno pump needed repairing. *Total = 3 days stoppage.*

Table 14A. Data Summary

Test: Inhibited JP-5 Fuel Test in accordance with MIL-F-8901 Fuel Flow: 20 gpm[a]
F/C Element: Banner, Model No. C-2037-3 Anti-Icing Additive Concentration: 0.15%

Inhibitor	Corrosion Inhibition Concentration (lb/1000 bbl)	Pressure Differential (reading at end of test) (psi)	Free Water Content (total less blank) (ppm)	WSIM	Total Testing (minutes)
1. Santolene-C (Hitec E-515)	16	16.0	1.5	47	130
2. AFA-1	12	9.5	0.5	41	130
3a. Lubrizol 541	6	9.5	5.2 Failure	41	60
3b. Lubrizol 541	6	15.0	5.9 Failure	41	110
3c. Retest of 3b	0	18.0	0.0	–	60
4. Tolad 244	6	17.5	2.4	60	130
5a. Tolad 245	12	12.0	5.4 Failure	71	30
5b. Retest of 5a[b]	0	13.5	0.0	–	60
5c. Tolad 245	12	19.0	5.9 Failure	71	90
5d. Retest of 5c[b]	0	19.0	0.3	–	60
6a. PRI-19	4	12.0	5.5 Failure	46	30
6b. Retest of 6a[b]	0	13.5	0.2	–	60
6c. PRI-19	4	12.0	5.3 Failure	46	60
6d. Retest of 6c[b]	0	12.5	0.1	–	60
7. Santolene CM (Hitec E-534)	8	15.0	0.5	52	130
8. DCI-4	8	12.0	0.4	50	130
9. Conoco T-60	16	12.0	0.1	51	130
10. Nalco 5400-A	8	15.0	0.0	45	130
11. Unicor-J	8	17.0	0.1	63	130
12a. Nalco 5402	8	14.0	7.4 Failure	48	65
12b. Retest of 12a[b]	0	13.0	0.2	–	60
12c. Nalco 5402	8	16.5	5.9 Failure	43	95
12d. Retest of 12c[b]	0	17.0	0.5	–	60

(a) In all instances where AC test dust was being injected in combination with 1% water, the flow rate dropped below 20 gpm. This was due to the pressure build-up inside the filter/coalescer element.

(b) All retested elements were the original elements that had failed the inhibited test.